Do linkages between farmers and academic researchers influence research productivity? Evidence from Mexico[1]

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Abstract

We explore the effect of linkages between farmers and academic researchers on research productivity in fields related to agriculture. We found a positive and significant relationship between intensive linkages with a few farmers and research productivity, when this is defined as publications in ISI journals. This evidence contradicts other contributions that argue that strong ties with businesses reduce research productivity and distort the original purposes of university. When research productivity is defined more broadly adding other types of research outputs, the relationship is also positive and significant, confirming the argument that close ties between public research institutions and businesses foster the emergence of new ideas that can result in valuable innovations. Another finding is that researchers in public institutions produce several types of research outputs; therefore, measuring research productivity only by published ISI papers misses important dimensions of research activities.

Introduction

Knowledge and intellectual talent have increasingly been recognized as the main determinants of development. Universities play a key role in this process, as they prepare highly trained professionals and generate scientific knowledge. However, universities have recently been called to focus more on generating knowledge that can have direct economic or social impacts [1]. Thus, it has been argued that linking universities with businesses could foster the emergence of new ideas that could lead to valuable innovations. While this new role of universities has been accepted by policy-makers, it has not been equally received by the scientific community ([2], [3]).

[1] This paper is part of a research project "Mejorando la Administración del Conocimiento en el Sistema de Innovación Agropecuario Mediante el Fortalecimiento de las Capacidades de las Fundaciones Produce, el SNITT e Institutos de Investigación" carried out in UAM and funded by SAGARPA-CONACYT (Project num. 2006-C01-48511).
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In fact, critics contend that stronger ties with businesses could distort the original purposes of universities and public research centers (PRC)[4] if they become more concerned with developing commercially-valuable products, than with conducting basic research and preparing highly trained professionals [2].

A growing body of literature studies university/PRC-businesses linkages. Most authors have focused on linkages between academic researchers, using as an indicator of research productivity the number of papers in ISI journals.[5] Some authors found that academic collaborations increases research productivity ([4], [5], [6]). On the other hand, the impact of collaboration between researchers and non-academic agents on research productivity has been less explored. On this respect, [5] and [6] found that university-businesses collaboration has a negative impact on research productivity. However, researchers generate several research products. Because of this diversity, the number of ISI papers is a poor indicator of research productivity [7]. This paper explores how the production of different research outputs in agriculture related fields is affected by collaborations between academic researchers and farmers.[6]

Researchers of research productivity have focused on different units of analysis: academic institutions, research teams or individual researchers, and have largely explored collaboration between academic researchers. When analyzing academic researchers-businesses collaboration, most of the literature has focused on the manufacturing sector or on new technologies. The topic has not been thoroughly explored in the agricultural sector, or in Mexico and other developing countries. We found only one paper that analyzed the determinants of research productivity and impact of individual Mexican researchers [8].

The empirical analysis is based on a survey of researchers working in Mexican public universities or PRC. The researchers were asked to identify how many of four types of outputs (papers published in ISI journals, crop varieties, agricultural recommendations and new techniques) they produced in the three years previous to the survey, and to identify different types of interactions with farmers.

Section I reviews the particularities of agricultural research. Section II reviews the literature on research productivity and presents the conceptual framework. Section III explains the research methodology. Section IV presents and discusses the main findings, and Section V concludes.

I. Particularities of agricultural research

Patterns of research and innovation vary across sectors [9]. A great deal of variation also characterizes agricultural research, which includes, among other disciplines, chemistry, biotechnology, engineering, plant breeding, entomology, agronomy, veterinary sciences, and forest management. In the last three decades, agricultural research has been expected to contribute to solve farmers' problems, create new business opportunities and address environmental issues; therefore, agricultural researchers are now expected to show the impacts of their research. The nature of the expectations about agricultural research and of the links researchers establish with other agents in the innovation system has changed over time as new insights on innovation processes were gained [1].

Until the early 1990s, public research systems in most developing countries sought mainly to increase the productivity of staples [10]. The

[4] Mexican Public Research Centers as legal entities are defined by federal law. The law allows them greater independence in managing their resources than traditional public offices. Most PRC and research labs in Mexico operate under this legal regime.

[5] Institute of Scientific Information.

[6] The term agriculture is used in a generic sense and includes, in addition to crop and plant research, livestock, aquaculture, forestry, and other scientific disciplines (e.g. biology, biotechnology and physics) that generate research outputs that can be used in more applied agricultural research.

public research institutes were generally organized along the linear vision of science, which induced researchers to work in the experimental stations and discouraged them from linking directly with farmers [11]. Since then, the mandate of public research expanded to include more sophisticated agricultural products and markets, sustainability, and poverty alleviation. Although tackling these issues required new research capabilities, public agricultural research systems in developing countries (Mexico included) weakened as budgets shrank and researchers aged [12]; in fact, very few research institutions were able to develop the new capabilities they needed ([1], [10]).

Some researchers and other stakeholders realized that the techniques developed by the PRC were not massively adopted by farmers, and a perception that these institutes were not fulfilling their mandate emerged ([12], [10]). This perception, combined with new trends in the management of science, induced major changes in the organization of agricultural public research, which included a demand for more accountability. In Mexico, new incentives based on research productivity were introduced; the latter, however, was narrowly defined because it only included publications in indexed journals [13].

Agricultural research in Mexico is conducted in three types of institutions: 'general' universities and PRC, sectoral universities and PRC, and other regional organizations (universities, PRC and institutes) that also research non-agricultural topics or conduct other types of activities such as extension. The first group is integrated by large federal universities and PRC; they have a well diversified research portfolio that can include chemistry, medicine and social sciences. Usually, their research related to agriculture covers science-intensive topics, such as biotechnology and biology.[7] The sectoral universities and PRC work only on topics closely related to agricultural production, such as agronomy and plant breeding, but they do little work on post harvest and transformation of agricultural products.[8] Finally, the other regional organizations may have a diversified research portfolio, but their activities related to agriculture deal only with post harvest issues and processing of agricultural products.

Two agencies fund most of the agricultural research in Mexico: the national science and technology council (CONACYT) and the Produce Foundations (PF). The PF are farmer-managed foundations who administer public resources to fund research, extension and innovation projects in the agriculture sector ([13], [11]). Another important source of funding for some Mexican researchers is the National Researchers System (NSR), which is managed by CONACYT.[9]

We grouped research outputs into four categories: papers in scientific journals, new recommendations, new techniques and new plant varieties. Papers are valuable (for the public incentives system) only when published in ISI journals; new recommendations include novel ways of using known inputs or crops, such as new ways to apply fertilizer; new techniques include new inputs, new equipment or substantially new ways of using known inputs, such as no-till

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[7] The largest 'general institutions' are Centro de Investigación y de Estudios Avanzados, Universidad Nacional Autónoma de México and Universidad Autónoma Metropolitana.

[8] The most important agricultural PRC is the National Institute for Forestry, Agricultural and Livestock Research (INIFAP); other relevant sectoral universities are the Postgraduate College, Chapingo Autonomous University and Antonio Narro University.

[9] The NRS was created in 1984 and its main objectives include supporting the formation, development and consolidation of a critical mass of high-level researchers, mainly inside the public system. It grants researchers pecuniary (monthly compensation) and non-pecuniary (status and recognition) incentives based on their productivity and the quality of their research.

practices;[10] and new plant varieties are seeds or plants developed to express a particular property, such as higher yields. Development of each type of output requires particular interactions with farmers (see section IV).

II. Academy-industry linkages and research productivity

Interdisciplinary and the increasing cost of modern science encourage scientists to get involved in collaborative research [14]. Collaboration among different types of agents is often viewed as a positive factor for knowledge creation and problem-solving [33].

For almost a century, the literature on the effect of collaboration on research productivity has mostly focused on interactions among academic researchers [4]. It has been argued that collaborations among scientist enhance research productivity because the greater 'interdisciplinarity' brings special expertise and knowledge crucial to research outcomes ([4], [3]). In other cases, it was found that collaboration is an important mechanism for mentoring graduate students and postdoctoral researchers, enhancing the productivity of individual scientists. The productivity of individual researchers has also been found to depend on institutional and organizational factors, including communication patterns, the degree of freedom to define personal research agendas, the recognition of the department in which researchers work, human resources, funding, mobility, teamwork, the size of research teams and recruiting policies by academic departments ([3], [15]).

[10] No-till is an agricultural technique in which seeds are planted in undisturbed soil. No-till is a complete agronomic package that requires adapted techniques for all stage of the plants' cycle, planting, plant and weed management, crop rotations, fertilization, and harvesting. Traditional planting, on the other hand, involves reducing the soil to a fine powder through intensive plowing and harrowing.

Ref. [5] found that a) science–science collaboration is related to the development of an academic career, while science–industry collaboration is not, b) all levels of network activity within the scientific community are positively related to each other; and c) academic rank and networking activity are strongly related, but interactions with industry show no relationship with academic rank.

In synthesis, the main reasons mentioned in the literature for academic collaborations include: to access special equipment, skills or materials; to gain recognition or visibility; to attain efficiency in the use of time or labor; to gain experience; to access trained researchers; to sponsor a protégé; to avoid competition; to surmount intellectual isolation; to confirm the evaluation of a problem; to share the escalating costs of science at the research frontier; to improve access to funds; to learn tacit knowledge about a technique; and to establish contacts for future work ([4], [5]). Despite the many reasons to expect collaborations to increase research productivity, the relationship is not obvious ([4], [14]). In fact, the benefits of collaboration for science have been more often assumed than deeply investigated [14].

Collaborations between universities and businesses have been analyzed both from the universities' and the businesses' perspectives, but, the empirical evidence is scant [4]. Some authors found that these collaborations have positive effects on scientific production, development and economic growth [7]. The Triple-Helix model has addressed the importance of the interaction between universities, industries and governments in the processes of knowledge creation and diffusion [16].

Some scholars have argued that academics who join firms may actually become more productive in terms of the quantity and quality of their publications ([12], [17]). In contrast, other studies argue that university researchers who create or join firms reduce their research productivity [18]. Finally, ref. [7] indicates that while collaboration with non-academic partners may not result in direct academic benefits, they often yield indirect benefits that may eventually enhance academic productivity; these benefits result from exposition to a broader set of ideas and problems than those encountered while conducting only curiosity-driven research. However, micro evidence on impacts of collaboration with businesses over research productivity is still limited.

Ref. [19] argues that the productivity of medical researchers in France, Germany, Britain, and the United States can be explained by the various degrees of competitiveness for research, the academic systems of these countries, the creation of specialized scientific jobs and facilities for research, and the introduction of large-scale systematic training. In addition, [20] found that size (larger research efforts) and scope (diversified programs) influence research productivity in the pharmaceutical industry, and report that faculty size and academic accreditation are important for obtaining high publication productivity and impact.

Ref. [4] reported that older scientists, or at least those who had longer careers, had more time to develop 'scientific and technical human capital' and professional networks; therefore, it was not possible to distinguish the effect on productivity of age and career length from collaboration. [21] identified life-cycle effects, concluding that the expectation that the latest educated are the most productive is not 'generally supported by the data'. [22] noticed that researchers' productivity peaked about ten years after they obtained their doctoral degree. [8] found that age does not have a substantial impact on research output in the Mexican case.

III. Methodology

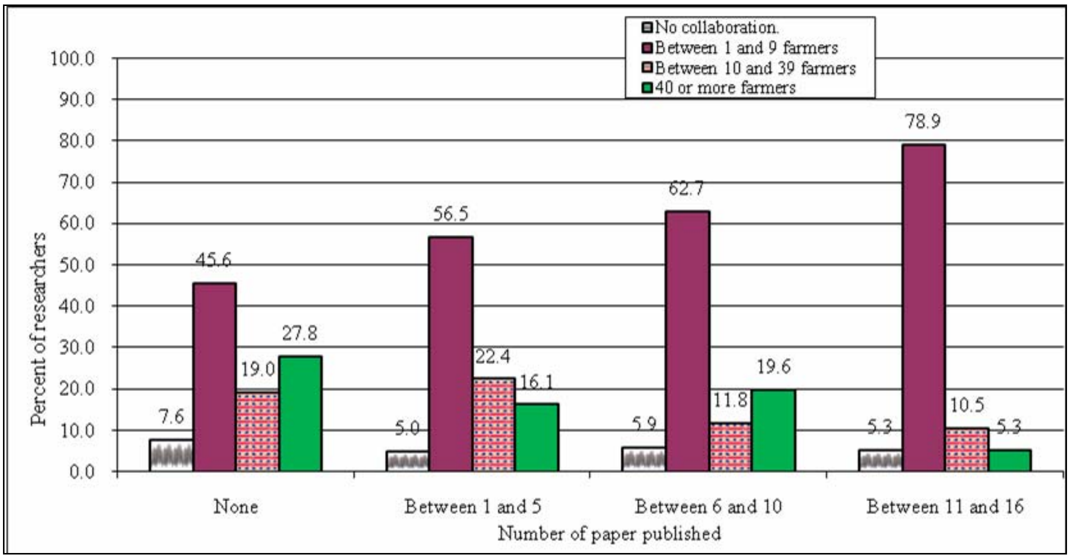
a) The data

The data used in this paper were obtained by surveying two partially overlapping groups of Mexican researchers who work on topics related to agriculture. The first group was identified from the NSR Database and the second group is integrated by researchers who had received grants from the PF in the last decade. The survey, conducted in 2008, covered the years 2006 and 2008 and contains 310 observations.

Most studies of research productivity have focused on researchers with doctoral degrees. In our survey, only 60.3 percent of researchers have a PhD, 32.6 percent have a Masters and 7.1 percent have a first college degree. Eighteen researchers did not report any collaboration with farmers, 174 collaborated with small groups (between 1 and 9 farmers), 59 interacted with medium-sized groups (between 10 and 39 farmers), and the same number partnered with large groups (more than 40 farmers).

Graphics 1, 3 and 4 show that for these research outputs (published papers, recommendations or techniques) researchers who collaborate with small groups of farmers are more productive than researchers who collaborate with large groups. In other words, the intensity of the relationship, which is stronger when researchers interact with small groups, seems to have a larger impact on productivity than the number of interactions (see section IV). On the other hand, graphic 2 shows that the number of seed varieties liberated is independent of the pattern of collaboration.

Graphic 1.
Relation between collaboration and paper published (percents)

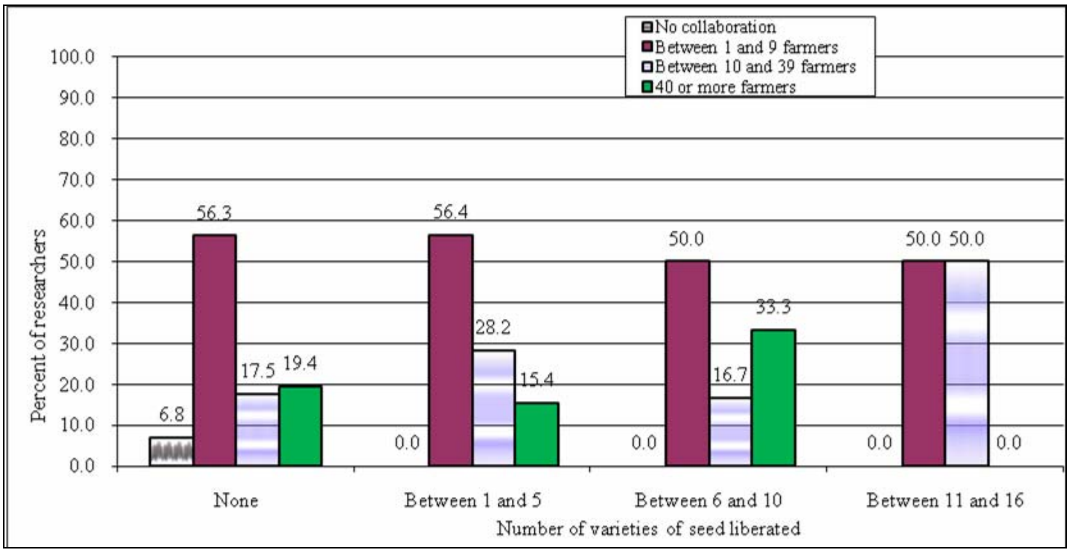


Absolute number of researchers	None	Between 1 and 5	Between 6 and 10	Between 11 and 16
	79	161	51	19
Percentage	25.5	52	16.5	6

Source: own elaboration.

Graphic 2.

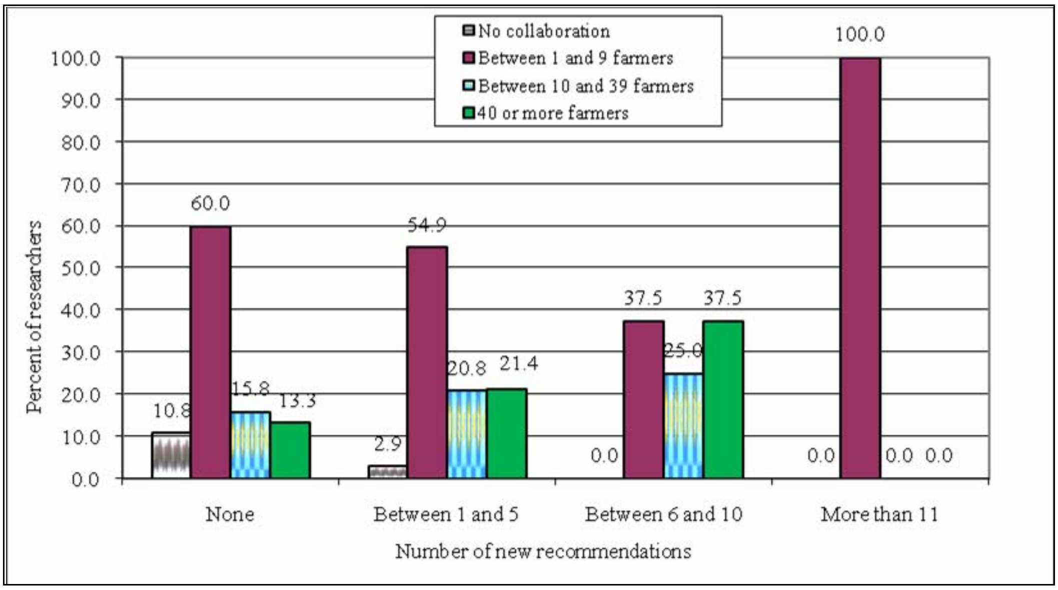
Relation between collaboration and number of seed varieties liberated (percents)



Absolute number of researchers	None	Between 1 and 5	Between 6 and 10	More than 11
	263	39	6	2
Percentage	84.8	12.6	1.9	0.6

Source: own elaboration.

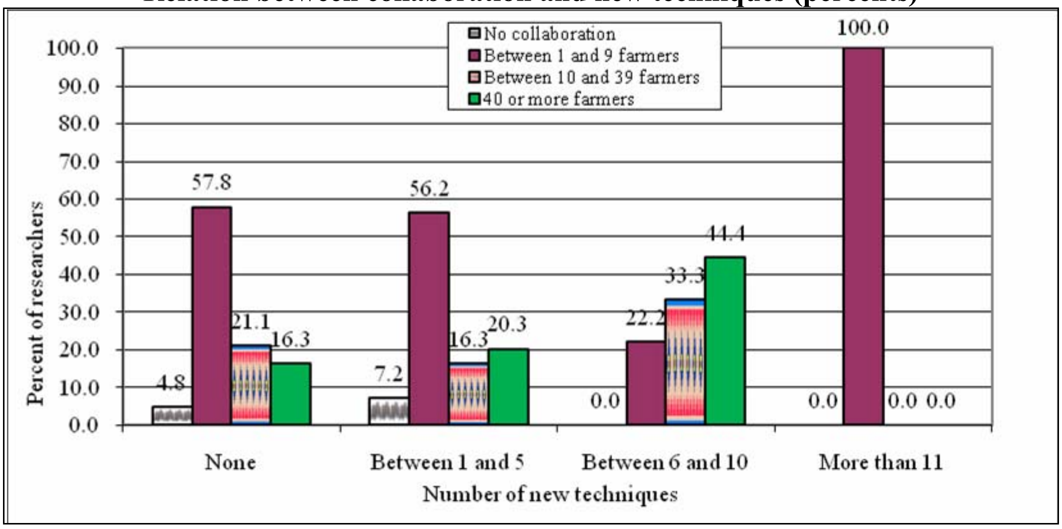
Graphic 3.
Relation between collaboration and new recommendations (percents)



Absolute number of researchers	None	Between 1 and 5	Between 6 and 10	More than 11
	120	173	16	1
Percentage	38.7	55.8	5.2	0.3

Source: own elaboration.

Graphic 4.
Relation between collaboration and new techniques (percents)



Absolute number of researchers	None	Between 1 and 5	Between 6 and 10	More than 11
	147	153	9	1
Percentage	47.4	49.4	2.9	0.3

Source: own elaboration.

b) The econometric model

As mentioned above, we identified four types of research outputs and we estimated separate ‘productivity’ functions for each of them. While the outputs were “released” in this period, the analysis of the projects funded in the last 10 years, showed that researchers had developed the links over several years. This allowed us to relate “recent” outputs with long-term, stable interactions. The independent variables are:

- *research_team*: takes the value 1 if the individual belongs to a researcher team and 0 otherwise.
- *link_producers*: is the number of interactions with producers reported by each researcher.
- *link0, link1, link2 and link3*: a set of dummies that take the value 1 if the researcher reports no linkages with farmers, between 1 and 9 interactions, between 10 and 39 interactions and more than 39 interactions.
- *inst_1:* the value 1 corresponds to researchers belonging to general universities and 0 otherwise.
- *inst_2*: the value 1 corresponds to researchers belonging to a sectoral PRC or university and 0 otherwise.
- *inst_3*: the value 1 corresponds to researchers belonging to small institutes that also conduct some research and 0 otherwise.
- *time_last_degree*: number of years between obtaining the highest academic degree and the year of the survey. We used this specification rather than age because graduate students from developing countries tend to be older than their counterparts from developed countries.
- *sqrtime*: the square of *time_ last degree* .
- *Mex degree:* takes the value 1 if the individual obtained her/his last degree in Mexico and 0 otherwise.
- *num_research_team*: is the number of researchers that participate in the research team, regardless of their academic degree.
- *sqr_num_research_team*: the square of *num_research_team*.
- *activity1, activity2 and activity3*: a set of dummies that take the value 1 if the researcher conducts basic research, applied research or technology development.

To write a paper, researchers need to conduct experiments or collect information. They can do both without interacting with farmers. Interactions, however, can help researchers to focus their research, experiment with alternative approaches and identify new research questions. As was mentioned above, there is a general consensus between researchers that stronger collaborations with businesses hamper the researchers’ ability to publish. Therefore, we expect a negative correlation between collaborations and publications.

To develop new recommendations or techniques, researchers need to understand the production processes in which they hope the innovations will be integrated. They can gain this understanding by a) the researchers being farmers themselves, b) interacting with farmers or, c) if the production process is relatively stable and well known (such as planting cereals and oilseeds), reading books or talking to other researchers. But the odds that the recommendations or the techniques will be adopted increase when researchers develop them interacting actively with farmers. Therefore, we expect a positive correlation between collaborations with few farmers and issuance of recommendations or techniques.

Finally, to develop a new plant variety, breeders need to have a clear understanding of what they are looking for (e.g., higher yields).

Again, they can get this understanding from a number of sources that may include farmers. But once they define the objective, they do not need to interact with farmers until the final stages of the development process (usually, after eight cycles of genetic improvement), and even at this stage the advantages of collaboration are not clear [23]. Thus, we expect no correlation between the release of new varieties and collaborations with farmers.

Because all dependent variables have a skewed distribution, the model was estimated with a negative binomial distribution using Maximum Likelihood estimators. We chose this distribution over a Poisson function because the former is more flexible; a likelihood ratio test of over-dispersion supported this decision.[11] Some researchers did not complete the whole questionnaire; therefore, only 290 observations were used in the estimations.

IV. Findings

The estimations show that the production of each output is influenced by specific factors.

Table 1 presents different specifications for the "production" of ISI published papers. The first column indicates that researchers publish more as they consolidate their careers but at a decreasing rate. The marginal significance of the coefficients, though, does not allow making a strong claim. The coefficient for having a Mexican degree in column 2 is clearly significant with a negative sign indicating that researchers who studied abroad have a preference for publishing papers. Introduction of this variable makes the coefficient for the years as professional non significant. The size of the research team has a positive effect on publications, but at a decreasing rate; this agrees with other authors who stress the importance of scientific networking (e.g. [4], [5]). The variable that identifies researchers who do not interact with farmers is not significant; this result is probably caused by the small number of observations in this category. Having a large number of collaborations negatively affects the propensity to publish. In general, researchers can relate to farmers in three ways: they can interact intensively with a few farmers, they can develop weak interactions with large numbers of farmers, like presentations in field days, or they can report as interactions work they expect will benefit farmers without interacting with the farmers themselves. In fact, the latter was the explanation researchers gave when asked how they interacted with thousands of farmers. The variables for the interactions show that the researchers who have large numbers of interactions (in other words, weaker interactions) tend to publish less than researchers who interact closely with a few farmers.

The institutional effects are strong. Sectoral universities and PRC perform more applied work and conduct more extension-like activities; therefore, they tend to publish less than 'general' university researchers. Additionally, belonging to "regional universities, PRC and institutes" does not influence publication rates. This is an ill defined category that includes highly regarded institutes and small teams that develop engineering processes. Similarly, in column 3 the dummies indicating applied research and technology development have negative signs and are significant; in other words, the type of research conducted influences publication patterns.

[11] See [24]. All the estimations in this section were performed using Stata 9.0.

Table 1. ISI published papers

	1	2	3
time_last_degree	0.039	0.028	0.022
	-1.47	-1.05	-0.85
sqr_time_last_degree	-0.002	-0.001	-0.001
	(1.99)*	(1.65)+	-1.47
Mex degree		-0.321	-0.334
		(2.31)*	(2.39)*
link_0	-0.058	-0.086	-0.06
	-0.22	-0.33	-0.23
link_2	-0.234	-0.193	-0.235
	-1.35	-1.12	-1.35
link_3	-0.345	-0.282	-0.247
	(1.96)+	-1.6	-1.38
inst_2	-0.267	-0.275	-0.362
	(1.88)+	(1.96)+	(2.62)**
inst_3	0.161	0.158	0.107
	-0.69	-0.68	-0.46
num_research_team	0.04	0.037	
	(3.52)**	(3.19)**	
sqr_num_research_team	-0.0005	-0.0004	
	(2.68)**	(2.33)*	
activity 2			-0.481
			(1.95)+
activity 3			-0.751
			(2.50)*
Constant	1.131	1.429	2.188
	(5.24)**	(5.72)**	(6.94)**
Observations	290	290	290
LR chi2(7)	39.83	45.2	39.88
Prob > chi2	0	0	0
Pseudo R2	0.0285	0.0324	0.0285
Absolute value of z statistics in parentheses			
*+ significant at 10%; * significant at 5%; ** significant at 1%*			

Table 2. New seed varieties, new recommendations and new techniques

	seed varieties	seed varieties	Recommendations	Recommendations	new techniques	new techniques
	1	2	3	4	5	6
time_last_degree	0.045	0.014	0.024	0.021	0.04	0.041
	-0.51	-0.16	-0.99	-0.86	-1.48	-1.53
sqr_time_last_degree	-0.0004	0.001	-0.0004	-0.0002	-0.001	-0.0005
	-0.15	-0.21	-0.62	-0.39	-0.77	-0.66
research_team	0.585		0.452		0.57	
	-1.2		(2.72)**		(3.01)**	
Mex degree	-0.544	-0.766	0.088	0.065	0.103	0.089
	-1.03	-1.51	-0.51	-0.38	-0.54	-0.47
link_0	-17.126	-16.796	-0.699	-0.737	0.326	0.281
	-0.01	-0.01	(1.85)+	(1.96)+	-0.93	-0.81
link_2	0.331	0.23	0.06	0.107	-0.174	-0.108
	-0.62	-0.43	-0.31	-0.55	-0.76	-0.47
link_3	-0.671	-0.592	0.39	0.401	0.331	0.477
	-1.15	-1.1	(2.07)*	(2.12)*	-1.54	(2.23)*
inst_2	2.519	2.245	0.367	0.408	0.408	0.457
	(4.57)**	(3.99)**	(2.21)*	(2.46)*	(2.14)*	(2.38)*
inst_3	-15.761	-15.982	-0.656	-0.659	0.468	0.371
	-0.01	-0.01	(1.89)+	(1.90)+	-1.44	-1.14
num_research_team		-0.065		0.028		0.032
		-1.53		(2.13)*		(2.17)*
sqr_num_research_team		0.0008		-0.0003		-0.0003
		-1.39		-1.54		-1.16
dummy_researchactivity2	1.374		0.56		0.349	
	-1.22		-1.58		-0.9	
dummy_researchactivity3	1.313		0.287		0.613	
	-1.04		-0.72		-1.42	
Constant	-4.339	-1.866	-0.841	-0.164	-1.349	-0.82
	(2.82)**	(2.09)*	(1.96)+	-0.59	(2.75)**	(2.68)**
Observations	290	290	290	290	290	290
LR chi2(7)	41.62	39.64	35.21	29.8	25.07	23.07
Prob > chi2	0	0	0.0002	0.0009	0.0089	0.0105
Pseudo R2	0.0964	0.0918	0.0342	0.029	0.0276	0.0254

Table 2 shows the results for the other four research outputs. The regressions show that the release of new seed varieties depends only on institutional factors. This was expected because in Mexico only sectoral institutes have plant breeding programs.[12]

[12] There are a few private nurseries and international breeding programs but they were not captured by our sample.

The development of new recommendations is not influenced by professional experience or by having a Mexican degree. Conversely, interacting with farmers has positive effects; even more, not interacting with farmers has a negative effect. We do not have a good explanation for why interacting with large numbers of farmers fosters developing new agronomic recommendations. As expected, there are strong institutional effects (column 3), since the mandate of sectoral universities and PRC include attending the farmers' needs. The negative coefficient for the "regional universities, PRC and institutes" reflects the fact that these do not research on agronomy but on other stages of agricultural chains. Finally, the size of the research team (column 4) has a positive effect on the development of new agricultural recommendations.

The development of new techniques is positively influenced by participation in a research team, by interacting with large numbers of farmers and by institutional factors (column 5). As in the previous cases, we do not have a good explanation for the positive effect of interacting with many farmers. The size of the research team (column 6) also has a positive effect in this case.

The fact that having a Mexican degree is significative only in the equation for the number of published papers indicates that in sectoral universities and PRC as well as in regional universities, several researchers do not have a doctoral degree (which hampers integration into research networks) and also that the pressure to publish is weaker in these institutions than in general universities.

V. Conclusions

The analysis of research productivity has attracted the attention of several researchers. It has been argued that research productivity is influenced by the interactions between researchers and also with businesses. While there is consensus among researchers on the positive impact of academic collaboration on research productivity, there is no such agreement on the effect of academy-businesses interactions.

Most empirical analyses have used a rather narrow definition of research productivity, i.e., number of papers published in indexed journals. However, researchers generate a variety of products, and they should also be used to measure productivity.

Research productivity changes according to the type of research conducted. Some types of research require a closer interaction among academic researchers and users of their outputs, while others can be conducted at arm's length. This is true not only for broad definitions of research areas (such as medicine) but also for narrowly defined lines of research such as agricultural basic science, crop improvement, issuance of agricultural recommendations and development of new techniques. Our results indicate that the influence of interactions between academic researchers and farmers is specific for each type of research. Thus, it is positive for published papers, agricultural recommendations and techniques when researchers link intensively with a few farmers and not significant for developing new seed varieties. But the influence of interactions becomes negative when researchers interact with larger number of farmers, and therefore, the interactions become less intense. Additionally, our research confirms that interactions among researchers unmistakable have a positive effect on research productivity for most research outputs.

Our findings have important policy implications. In many developing countries incentives offered to researchers are based on the number of papers published in ISI journals. While this fosters publications, it does not favor the development of solutions to problems faced by businesses or society. Therefore, incentives for other research products should be added.

Our results are preliminary in nature. Future research will explore whether the research productivity function follows a power law distribution. We will also explore the joint influence of other variables on research productivity, in particular, the influence of not only the number of linkages but also of their nature, and to what extent there are different profiles of researchers that require different measures of research productivity.

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